Assessing the impact of urban greenspaces on $PM_{2.5}$ spatiotemporal variability in Riga, Latvia, via citizen science and low-cost sensors

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Introduction

Representative $PM_{2.5}$ measurement is crucial for air quality (AQ) management, exposure assessment, and public health protection.

Yet, the density of $PM_{2.5}$ monitoring networks varies by region, and official network designs do not address low-exposure microenvironments like urban greenspaces.

Why urban green matters? It's a key predictor in:

- Spatial $PM_{2.5}$ **exposure models**
- Health **impact assessment** (Dadvand et al, 2014)

Case Study: Riga, Latvia:

- Only a **few AQ studies** in Riga (Ramacher et al., 2019), despite its size and capital city status
- **New $PM_{2.5}$ monitoring network** deployed using calibrated **low-cost sensors (LCS)**

Network Design Goals:

Capture exposure contrasts across Urban Green (UG), Near Green (NG), Near Traffic (NT) and Traffic locations (T) (Grivas et al., 2019)

Methodology

Instruments: Purple Air PA-II monitors (field calibrated)

Field calibration:

at – NOA Thissio UB Supersite in central Athens (Dimitriou et al., 2023); vs – reference-equivalent Beta monitor; for – 2 months (Feb.-Apr. 2024)

Riga Monitoring network:

20 calibrated LCS in Riga, Latvia, deployed in a Citizen Science (CS) framework (UG: 5, NG: 5, NT: 8, T: 2)

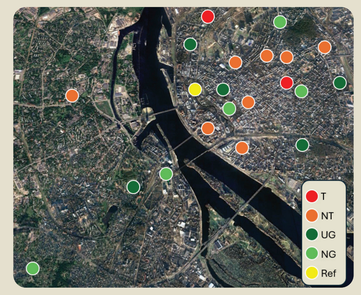
Study periods: September 2024 – August 2025:

i) Warm Period (June-August)
ii) Cold period (November-March)
iii) Transition period (September-October, April-May)

Ancillary data:

Reference $PM_{2.5}$ at Kronvalda blv site, met. data (Rīga-Universitāte), Urban Atlas, OSM, GHSL

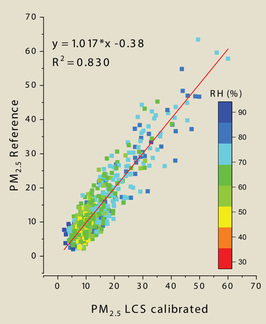
Above: Calibration in Athens
Below: Deployment in Riga



Calibration

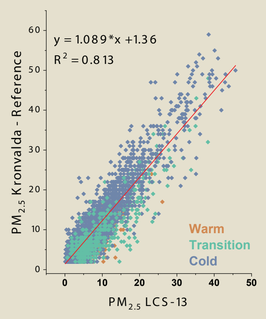
Field Calibration

- Bivariate regression models, including RH as a covariate.
- Pooled corrected LCS 1-hr concentrations vs. collocated reference in the Figure
- Excellent R^2, near-unity slope, near-zero intercept.



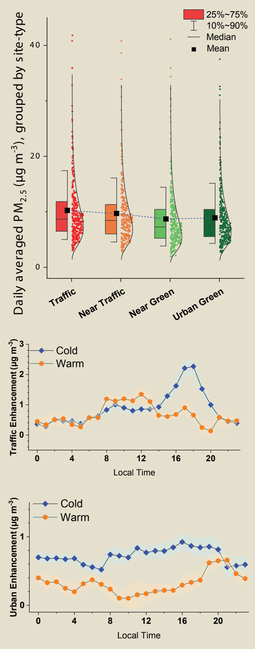
Field Validation - Riga

- 3 LCS in close distance to the official Kronvalda blv station.
- All LCS correlated highly vs the reference (r: 0.88-0.90, n> 4500).
- Low biases for the nearest site (LCS-13, 0.6 km; Figure).



Spatiotemporal Contrasts

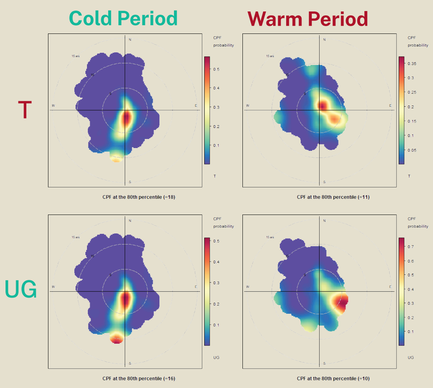
- 65% of sites had annual concentrations ≥10 μg m^{-3}.
- The frequency of daily values >25 μg m^{-3} was <5%.
- Moderate mean traffic (T-NT, 8%) and urban (NT-UG, 7%) enhancements. The former peaked in winter evenings.
- Benefits from vegetation buffering also for near-green residential sites.
- Cold vs. warm period increases (36-47%) across site types show the effect of city-wide winter emissions (limited domestic heating effects in the city center).



Wind Analysis

Conditional Probability Function analysis (CPF at the 80º), for $PM_{2.5}$ associations with wind direction/speed.

- Cold period events related to stagnant conditions at all sites. High background levels appearing during strong southerlies.
- Warm period background elevated for advections from the SE, which can also affect T-NT sites.



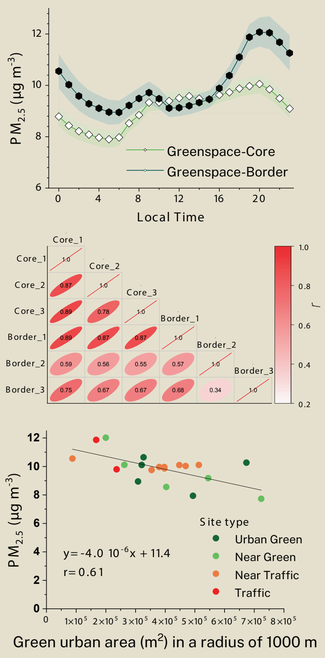
Urban Green Effects

Contrast between LCS in:

- The border zone of a greenspace
- UG sites in the core of greenspaces (>100m from a road)

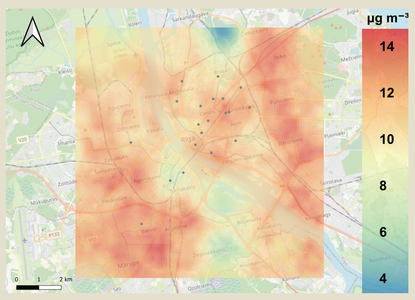
Border zone UG sites affected by local sources, displaying bimodal cycles and lower correlation with core UG sites.

Annual mean $PM_{2.5}$ per site inversely correlated with urban greenspace area within a 1 km radius around sites (GIS variable, Urban Atlas)



Spatial modeling

- Land-use regression (LUR) model developed based on annual mean concentrations from 20 sites.
- Examined predictors: LU (residential, urban green, industrial, transport, natural), road network (lengths and distances from sites), population. Area variables in 7 buffers (25-2500m) around sites.
- 4-parameter LUR model (**urban green** within 1km, **residential** land use within 50m, **natural** areas within 2.5km, inverse **road distance.** LOOCV (leave-one-out cross-validation) R^2 = 0.83.



Annual mean $PM_{2.5}$ spatial variability in the greater area of Riga based on LUR modeling

Conclusions

- Field validation demonstrated that calibrated LCS provided reliable measurements with low bias.
- First high-resolution AQ monitoring network in Riga showed clear spatiotemporal $PM_{2.5}$ contrasts.
- Urban greenspaces were consistently linked to exposure reduction, but do not fully isolate from transport/ domestic emissions.
- The observed contrasts warrant the need to expand the regulatory AQ network in Riga, in view of the updated EU AQ directive, as annual-LV exceedances are probable.
- The data from the calibrated LCS network can support AQ management and urban planning in the Region of Riga.
- The network's potential expansion can lead to efficient spatial modelling, exposure assessment, fusion with CTM, and uptake by health studies.

References

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